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Strangeness Production at Mid-Rapidity in S + Pb Collisions at 200 GeV/c per nucleon

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June 1992

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Abstract

Experimental evidence is presented for a source of unusually high strangeness content located at mid-rapidity in 200 GeV/c per nucleon collisions of ^{32}S projectiles with a Pb target. The enhancement is not seen in p + Pb reactions measured in the same apparatus at the same energy. This source becomes dominant for central collisions.

The formation of a deconfined phase of quarks and gluons, the Quark-Gluon Plasma (QGP), is predicted to occur in heavy-ion collisions when the energy density is sufficiently high [1]. Many signatures of plasma formation have been suggested [2]. The NA36 experiment at the CERN SPS was designed to investigate the proposed strangeness enhancement originating from the QGP phase of nuclear matter [3]. While the total strangeness content of the reaction may not itself be a direct signal of plasma formation, the characteristics of the distributions of strange and anti-strange baryons provide a useful means of distinguishing between hadronic gas and QGP scenarios [4].

A high statistics measurement of neutral strange particle production has been made by the NA36 experiment in S + Pb collisions at 200 GeV/c per nucleon. These measurements were made using a Time Projection Chamber especially designed for the high multiplicity environment of heavy-ion collisions. The data cover event negative multiplicities up to 250 tracks in the rapidity range $1.25 < y < 3.5$ and transverse momenta $0.2 < p_{\perp} < 2.0$ GeV/c. The charged decay of Λ, $\bar{\Lambda}$ and K^o particles was identified by their characteristic V^o topology. Details of the experimental apparatus and the analysis methods have been described previously [5]. The invariant mass distributions resulting from the analysis are shown in fig. 1. The resolution in the mass peaks is 6 MeV for the Λ and $\bar{\Lambda}$ mass distributions and 7 MeV for the K^o mass distribution. The background in the mass distributions is well understood. It has a combinatorial part, and there is a contribution due to overlap in the signal of different particle species. All particle yields have been corrected for background and the techniques that were used have been tested against Monte Carlo calculations. Examined sources of systematic error, such as absolute position of detectors, have been estimated to be less than 10% and independent of rapidity. The rapidity and transverse momentum distributions have been corrected for acceptance and trigger distortions. There are no corrections for the contributions of multiply strange particle decays to the data.

The transverse mass distributions for the three particle types are shown in fig. 2. Temperature information has been deduced by fitting the approximate Hagedorn formula[1] to the data [6]. In all cases the temperature is found to be of the order of 200 MeV. These results are in good agreement with those reported by the CERN experiment NA35 for S + S collisions at the same beam momentum [7]. The difference between these results and those reported by the WA85 experiment [8] in S + W collisions, is discussed by Rafelski et al. [9].

The rapidity distribution is an important indicator of the underlying reaction mechanism, since it helps to distinguish between the fragmentation regions and the central region. If the nucleus-nucleus reactions are a simple superposition of nucleon-nucleon collisions then Λ production should be concentrated in the projectile and target rapidity regions where the baryon density is highest. By contrast, $\bar{\Lambda}$ and K^o should be produced predominantly in the central region due to their sea quark content. Central rapidity for a reaction induced by a sulphur projectile impinging upon a lead target nucleus at 200 GeV/c per nucleon may be between $2.5 < y < 3.0$ in the laboratory frame. The precise position of central rapidity is dependent on the amount of stopping in the nuclear medium. The Λ, $\bar{\Lambda}$ and K^o rapidity distributions measured in this experiment are presented in fig. 3. In order to investigate the reaction mechanism we include, for comparison, the distributions produced by p + Pb reactions in the same figure. These p + Pb data were taken by NA36 with the same experimental apparatus and analyzed by the same software procedures [10]. The p + Pb distributions are not trigger corrected and are therefore plotted as $\frac{1}{N_{ev}} \frac{dN}{dy}$ vs y.

The striking feature in the ion data is the strong enhancement of Λ , $\bar{\Lambda}$ and K^o production near mid-rapidity. On the other hand, the peak of the Λ rapidity distribution in the proton data is in the target

1 The formula used is $\frac{1}{p_\perp} \frac{d\sigma}{dp_\perp} \propto \frac{1}{T} \sqrt{m_\perp} \exp\left(- \frac{m_\perp}{T}\right)$ where $p_\perp$ is the transverse momentum, σ the cross section, T the temperature, and $m_\perp = \sqrt{p_\perp{}^2 + m^2}$ the transverse mass.

rapidity region which is expected from standard reaction models. The contrast between the behaviour of the Λ rapidity distributions for proton and sulphur projectiles provides strong evidence that a difference in strangeness production mechanisms must exist in these two cases.

An enhancement of Λ production at mid-rapidity in S + S collisions has been reported by the NA35 collaboration [7]. The enhancement is much smaller than that shown here for S + Pb. This may be due to the smaller number of participants in the S + S reaction. The enhancement of production at mid-rapidity is a strong function of event multiplicity. This can be seen in fig. 4 where the ratio of the Λ and K^0 production cross sections at mid-rapidity to that at low rapidity is shown as a function of negative multiplicity. The ratio is approximately 0.8 at multiplicity 25 indicating the rapidity distribution is peaked more at target rapidity as one would expect from p + p reactions. However, above the multiplicity of 50 the mid-rapidity peak in the S + Pb production cross sections causes this ratio to be approximately constant at a value of about 2.5. This we see as evidence that the production mechanism changes when the reactions become more violent.

A large enhancement in the production of neutral strange particles in S + Pb collisions at mid-rapidity is reported in this paper. The $\bar{\Lambda}$ to Λ ratio of the integrated cross section in this portion of the data ($2.25 < y < 3.00$) is 0.38±0.05 which is a factor of 3 above p + p measurements [11][2]. This enhancement is strongly dependent on event multiplicity and saturates for central collisions at a factor of 3 above that seen at low multiplicities. The enhancement is not seen in p + Pb data and is also not predicted by models based on a superposition of nucleon-nucleon collisions and it may therefore be concluded that the data are indicative of another production mechanism. Rafelski et al. suggest that this behaviour can be explained under the assumption that the observed particles are consistent with the existence of a dense, deconfined fireball formed at mid-rapidity [9].

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2 In the limited region of acceptance $2.3 < y < 3.0$, $p_\perp > 0.9$ GeV the $\bar{\Lambda}$ to Λ ratio is reduced from 0.4 to 0.28±0.04. This value is slightly larger than the value of 0.19±0.01 quoted by WA85 in this region.[12]

Acknowledgments

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Figure captions

Fig. 1 Invariant mass distributions for Λ, $\bar{\Lambda}$ and K^o. The mass resolutions are 6, 6 and 7 MeV for Λ, $\bar{\Lambda}$ and K^o, respectively.

Fig 2. Transverse mass distributions for Λ, $\bar{\Lambda}$ and K^o.

Fig 3. Rapidity distributions for Λ, $\bar{\Lambda}$ and K^o for S + Pb and p + Pb reactions.

Fig 4. A comparison of the integrated cross sections for Λ and K^o production in S + Pb reactions for the mid-rapidity region ($2.25 < y < 3.25$) and the target rapidity region ($1.25 < y < 2.25$). The "cross section ratio" = $\dfrac{\sigma(2.25 < y < 3.25)}{\sigma(1.25 < y < 2.25)}$ is plotted as a function of the negative multiplicity of the reaction.

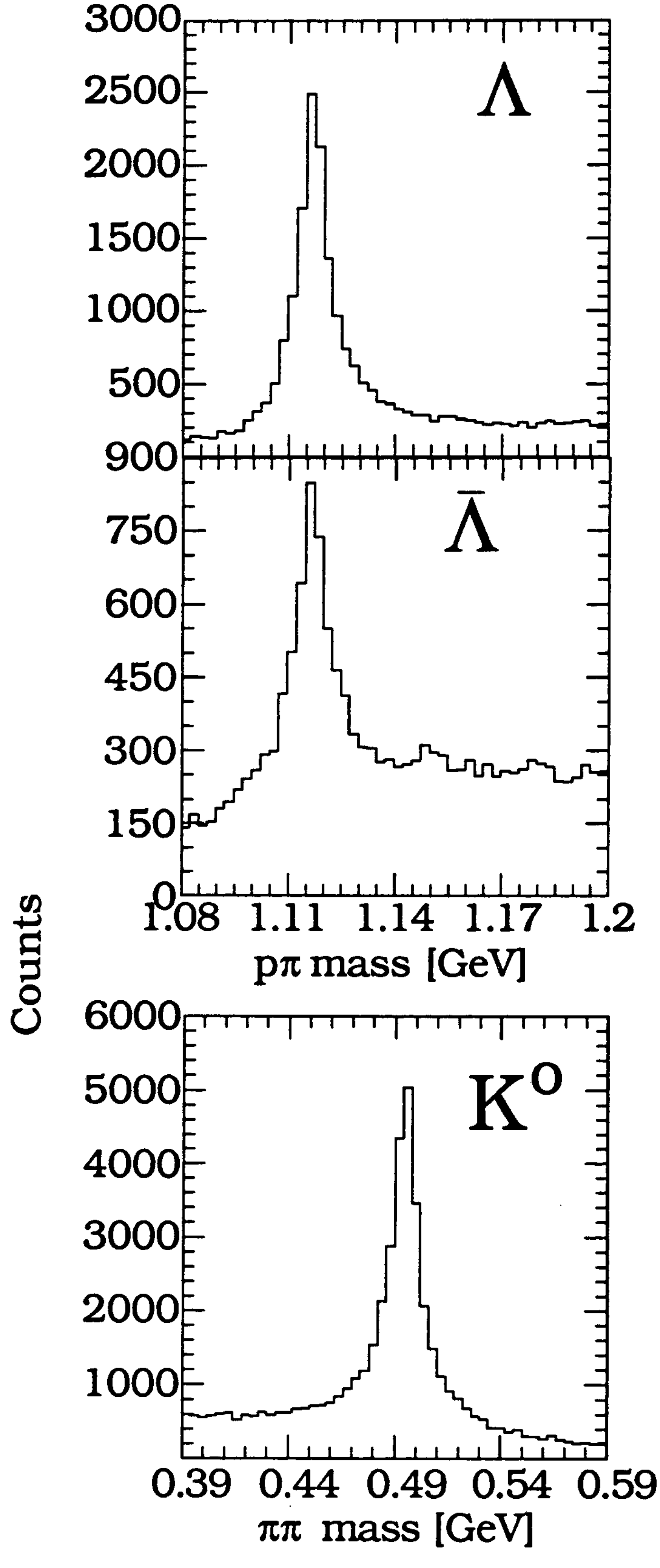
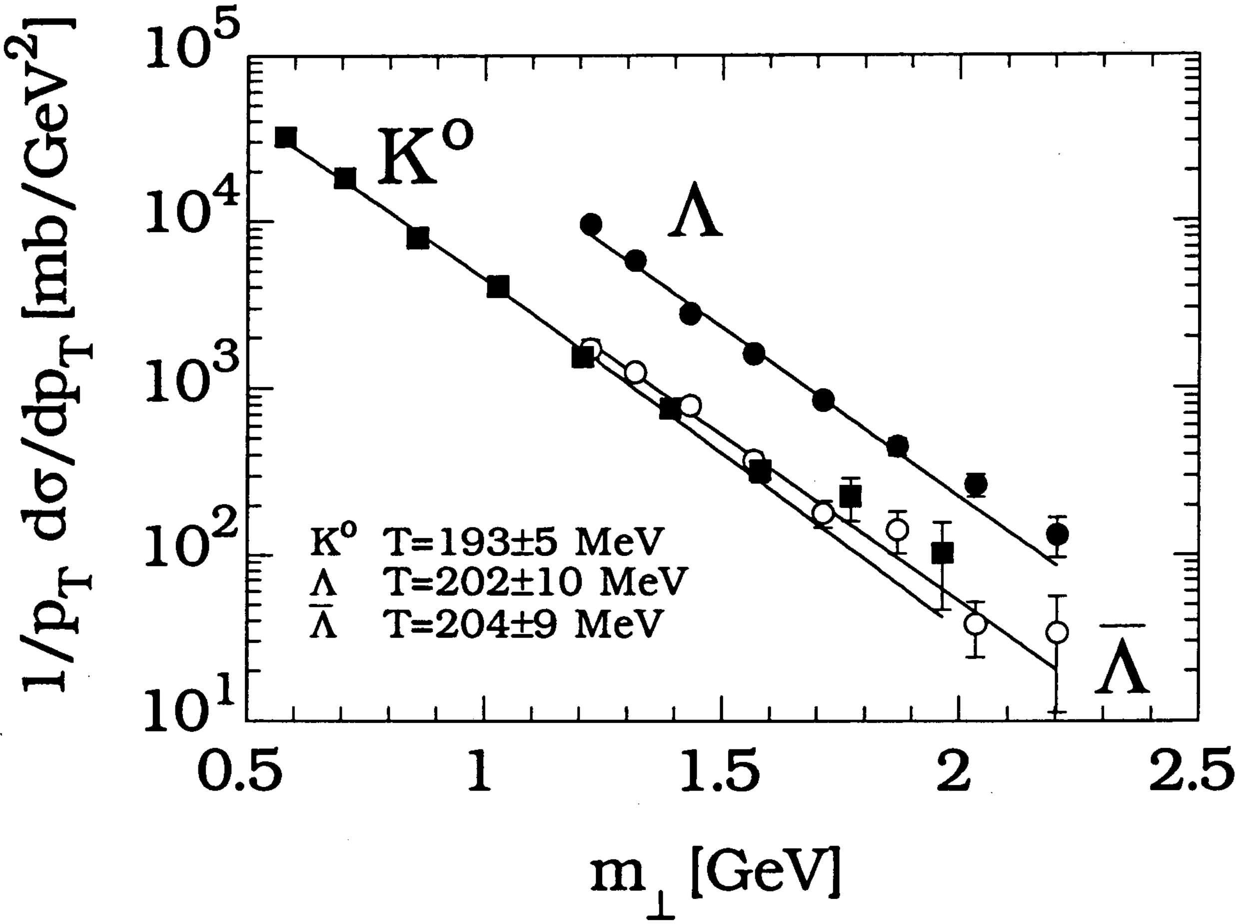

Λ
$\bar{\Lambda}$
K°
Counts
pπ mass [GeV]
ππ mass [GeV]
3000
2500
2000
1500
1000
500
900
750
600
450
300
150
0
6000
5000
4000
3000
2000
1000
1.08
1.11
1.14
1.17
1.2
0.39
0.44
0.49
0.54
0.59

Fig 1



10^5
10^4
10^3
10^2
10^1
$1/p_T\ d\sigma/dp_T\ [mb/GeV^2]$
K^o
Λ
$\bar{\Lambda}$
K^o T=193±5 MeV
Λ T=202±10 MeV
$\bar{\Lambda}$ T=204±9 MeV
0.5
1
1.5
2
2.5
$m_\perp$ [GeV]

Fig 2

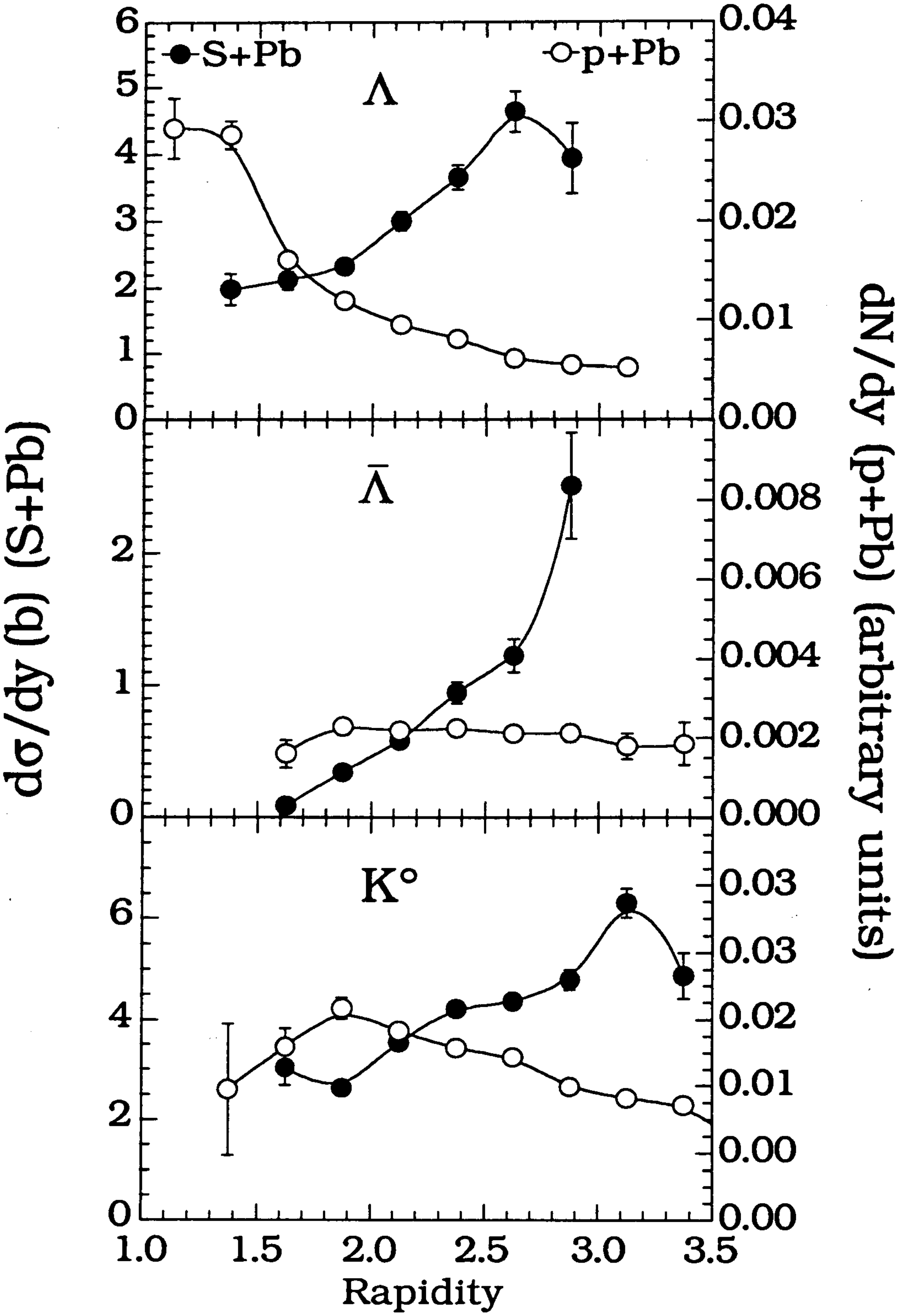
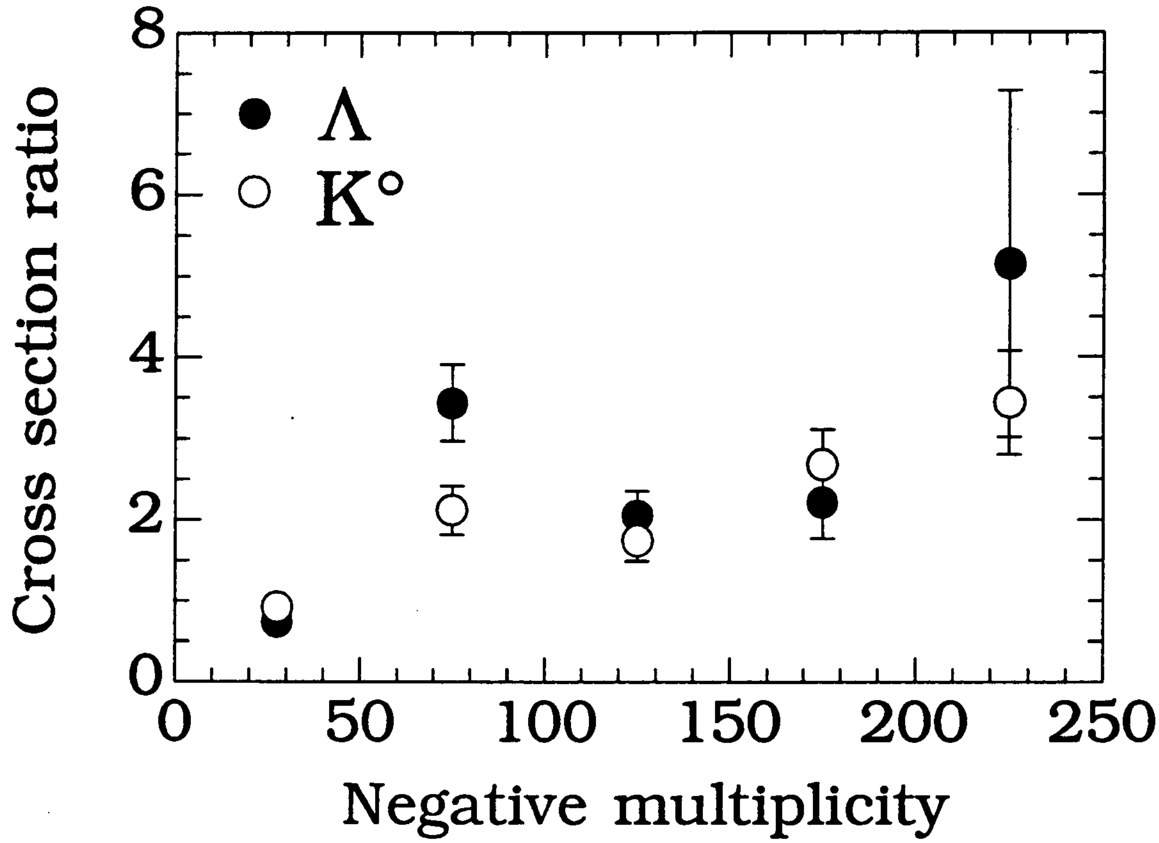

S+Pb
p+Pb
Λ
$\bar{\Lambda}$
K°
dσ/dy (b) (S+Pb)
dN/dy (p+Pb) (arbitrary units)
Rapidity

Fig 3



8
6
4
2
0
Λ
K°
Cross section ratio
0
50
100
150
200
250
Negative multiplicity

Fig 4

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